Hip Strength Deficits in People With Symptomatic Knee Osteoarthritis: A Systematic Review With Meta-analysis

Osteoarthritis (OA) poses a significant personal and global economic burden. The pathogenesis of OA is characterized by destruction of cartilage and subchondral bone and by synovial inflammation. Osteoarthritis typically presents in the weight-bearing joints of the lower limb, with knee OA being most prevalent. The slow deterioration of knee OA results in increased pain and reduced physical function in simple activities like walking, carrying objects, and housekeeping. An aging population and the elevated costs and adverse events associated with end-stage OA-related joint replacement surgery have contributed to the escalating global and economic burden of the disease. Research has therefore sought to optimize conservative interventions to reduce pain, improve physical function, and potentially delay disease progression.

A recent Cochrane review established high-quality evidence that lower-limb rehabilitation exercise can improve pain and physical function in people with knee OA. While the authors concluded that most forms of monitored rehabilitation programs are beneficial for this population, there was evidence to suggest that specific, individualized, and targeted exercise (e.g., quadriceps strengthening) was more effective than generalized lower-limb rehabilitation. The authors suggested that the optimum type and dose of targeted rehabilitation have yet to be determined; therefore, a complete understanding of all the impairments associated with the condition may help to identify the most relevant targeted strategies. Understanding hip strength deficits in people with knee OA may provide a promising avenue for targeted rehabilitation. There is some evidence to suggest that internal hip abduction moment (an

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**STUDY DESIGN:** Systematic review with meta-analysis.

**BACKGROUND:** A complete understanding of impairments associated with knee osteoarthritis would optimize exercise interventions for people with knee osteoarthritis. Our current understanding of hip strength deficits in this population is based on studies with conflicting findings and small samples. There is a need to systematically review and pool current evidence.

**OBJECTIVES:** To determine whether hip strength deficits exist in people with symptomatic knee osteoarthritis.

**METHODS:** Electronic databases (MEDLINE, CINAHL, Embase, the Cochrane Library, and PsycINFO) were searched through February 2016. Studies comparing hip strength in people diagnosed with symptomatic knee osteoarthritis to healthy control participants were included in the review. A meta-analysis with random effects was applied to relevant data from included studies and a modified Grading of Recommendations Assessment, Development and Evaluation approach was used to evaluate the quality of evidence for each pooled analysis.

**RESULTS:** Five studies were included in the review. Meta-analysis revealed moderate-quality evidence of weaker isometric and isokinetic hip abduction strength in people with knee osteoarthritis (moderate difference: 7% to 24% weaker) and very low–quality evidence of no difference in isometric hip adduction strength. There was very low–to moderate-quality evidence of weaker isokinetic hip strength in the remaining planes of motion (moderate to large differences: 14% to 55% weaker).

**CONCLUSION:** Significant hip strength deficits exist in people with knee osteoarthritis. Hip strength assessment should be considered in clinical practice and may assist with directing targeted management strategies.


**KEY WORDS:** dynamometer, muscle strength, muscle weakness
indirect measure of hip muscle strength) may be associated with knee OA. It has been hypothesized that hip abductor weakness can lead to the development of knee OA due to the resulting contralateral pelvic drop, shifting the center of mass and increasing load over the medial tibiofemoral joint. This hypothesis is not clearly supported by current evidence, due to conflicting results from independent studies with small sample sizes with regard to the presence of hip strength deficits in people with established knee OA. There is clearly a need to systematically identify and pool available literature to strengthen our confidence in the current evidence and best direct knee OA management. Furthermore, a recent systematic review identified knee extensor weakness as a risk factor for the development of knee OA. No review, however, has yet investigated the association between hip strength and development of knee OA. Compiling evidence of hip strength deficits and their association with the development of symptomatic knee OA may help to generate strategies to prevent knee OA development and progression.

The objective of this systematic review was to determine whether people with symptomatic knee OA have hip strength deficits when compared to a control group of healthy individuals. A secondary aim was to assess whether hip muscle strength is a risk factor for the development of symptomatic knee OA.

**METHODS**

This systematic review complied with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

**Search Strategy**

A comprehensive, systematic search of MEDLINE, CINAHL, Embase, the Cochrane Library, and PsycINFO databases was completed from the earliest date available until February 2016. The search strategy was modified according to the specifications of each database. Terms were searched under 2 concepts; population (knee OA) and outcome (hip strength) (Appendix, available at www.jospt.org). Synonyms within each concept were mapped to subject headings where possible and searched under title or abstract. Results within each concept were combined with the “OR” operator. The 2 concepts were combined with the “AND” operator and exported to EndNote reference management software (Version X7; Thomson Reuters Corporation, New York, NY).

Following removal of duplicates, titles and abstracts were screened by 2 reviewers using the eligibility criteria (M.D. screened all abstracts, A.S. abstracts A through L, and E.L. abstracts M through Z). Differences in opinion were resolved by consensus with the third reviewer. The full texts of remaining articles were obtained and screened by 2 reviewers (M.D., E.L.). Citation tracking and reference checking were also completed by 1 reviewer (M.D.) using Google Scholar.

**Selection Criteria**

Studies were selected according to pre-specified eligibility criteria. For the primary aim, only studies investigating people with an established diagnosis of unilateral or bilateral knee OA were included. Studies were only included if participants had symptomatic knee OA with radiographic confirmation. All other forms of arthritis were excluded. Only studies comparing knee OA to a healthy control group were included. Studies comparing hip muscle strength of the involved and uninvolved limbs in people with unilateral knee OA were excluded, as there is evidence of bilateral muscle weakness in people with unilateral pathology. This study was limited to case-control designs, prospective studies, and randomized controlled trials of interventions, where baseline measures of hip muscle strength were available. Only studies published in the English language were included. For the secondary aim, to investigate whether hip strength was a risk factor for the development of knee OA, studies had to include a measure of hip strength at baseline in people with no radiographic or symptomatic knee OA and assess the presence of symptomatic and radiographic knee OA at follow-up of 2 years or longer.

**Outcome Measures**

Measures of maximal isometric or isokinetic strength of isolated hip actions across all 3 planes of motion were extracted from the studies. Studies were only eligible if strength was measured with handheld or isokinetic dynamometry.

**Assessment of Risk of Bias**

The methodological quality of the studies was assessed separately by 2 reviewers using a modified Downs and Black tool. The tool was modified by excluding items that pertained to randomization or interventions, as the outcomes of this review related to noninterventional, observational data. A minimum risk-of-bias score was not a component of study eligibility.

**Data Extraction**

Data extraction was completed by 1 reviewer (M.D.) and checked by a second reviewer (A.S.). Data extracted included participant characteristics, control-group characteristics, scales used for OA diagnosis, unit of measurement for muscle strength, dynamometer type, and participant position. Classification systems for diagnosis of knee OA were also extracted for radiographic findings.

For the primary aim, means and standard deviations of hip strength were extracted for the purpose of calculating differences between groups. When necessary, standard deviation was extracted or calculated using available data (eg, confidence intervals [CIs]) or information presented in graphical format. Odds ratios were derived from dichotomous data of prognostic studies (secondary aim). Corresponding authors were contacted by e-mail when insufficient information was available.
FIGURE 1. Flow of studies through the review. Abbreviation: OA, osteoarthritis.

TABLE 1

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*1, Clear aim; 2, Outcomes described; 3, Participants described; 5, Confounders described; 6, Main findings described; 7, Estimates of random variability; 10, Probability values reported; 11, Participants are representative of the population; 12, Confounders comparable between groups; 15, Blinded assessors; 18, Appropriate statistical testing; 20, Valid and reliable outcome measures; 21, Participants recruited from the same population; 22, Participants recruited over the same time period; 25, Adequate adjustment for confounding.

Out of 15: 1 is yes and 0 is no.

**Data Analysis**

Standardized mean differences (SMDs; Hedges’ g) were calculated from means and standard deviations (mean difference/pooled SD) of muscle strength data using Review Manager software (Version 5.2; The Cochrane Collaboration, London, UK). The SMDs of 0.2, 0.5, and 0.8 were considered small, moderate, and large, respectively. The percentage difference in strength was also calculated to provide a further indication of the relative difference in strength between OA and control participants [(OA strength – control strength)/control strength × 100]. Results were grouped according to the type of strength measurement (eg, isometric or isokinetic) or hip action performed (eg, hip flexion or extension).

Data were pooled for multiple studies in a meta-analysis within each group using a random-effects model. When studies reported on multiple grades of OA classification (eg, Kellgren-Lawrence grade 2 or 3) without reporting on muscle strength of the whole sample combined, only the more established OA grading was used in the meta-analysis, to avoid repeated assessment of control-group data. When studies measured isokinetic strength at multiple speeds, the slower speed was used, as slower speeds are considered more reliable. When a study reported results of left and right knees of participants with bilateral knee OA, only the side with the most conservative SMD was presented, to avoid repeated inclusion of control-group data. Statistical heterogeneity across pooled studies was assessed using the I² statistic, in which a value of 25%, 50%, or 75% was considered a low, moderate, or high level of heterogeneity, respectively.

**Assessment of Quality of Body of Evidence**

A modified version of the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was used to evaluate the quality of evidence in each meta-analysis. The GRADE tool has been modified to apply to observational, nonexperimental data. Each meta-analysis was graded using the following predefined criteria: (1) inconsistency (downgraded if I² was 50% or greater), (2) indirectness (downgraded if clinically heterogeneous [eg,
### TABLE 2

**Characteristics and Results of Included Studies**

<table>
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<tr>
<th>Study/Design</th>
<th>Knee OA Participants</th>
<th>Control Participants</th>
<th>Strength Outcome Measure</th>
<th>Results*</th>
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</table>
| Baert et al⁴  | Group 1: established OA; n = 12; 12 female; age, 68.3 ± 6.8 y; radiographic severity; KL grade >2 | n = 14; 14 female; age, 65.8 ± 9.9 y | Isometric peak torque (Nm/kg): 30° abduction | Abduction  
• Established OA versus control: SMD, –0.57; 95% CI: –1.36, 0.22; –18.31%  
• Early OA versus control: SMD, –0.25; 95% CI: –1.00, 0.49; –70.46%† |
|              | Group 2: early OA; n = 14; 14 female; age, 65.4 ± 8.9 y; radiographic severity; KL grade <2 | n = 14; 14 female; age, 65.8 ± 9.9 y |  |  |
| Costa et al⁵ | OA: n = 50; 44 female; 25 unilateral, 25 bilateral; age, 56 y (range, 30-63 y); radiographic severity, classified according to KL grade, but no summary statistic provided | n = 50; 44 female; 25 matched to unilateral OA, 25 matched to bilateral OA; separate control participants matched to unilateral and bilateral OA groups; age, 57 y (range, 34-65 y) | Isokinetic peak torque (Nm): flexion, IR, ER, abduction, adduction, extension (30°/s); ROM not reported | Abduction  
• Unilateral OA versus control: SMD, –0.41; 95% CI: –0.97, 0.15; –14.28%  
• Bilateral OA right leg versus control right leg: SMD, –0.81; 95% CI: –1.39, –0.23; –31.53%  
• Bilateral OA left leg versus control left leg: SMD, –1.04; 95% CI: –1.64, –0.45; –34.87%  
• Adduction  
• Unilateral OA versus control: SMD, –1.07; 95% CI: –1.67, –0.47; –50.13%  
• Bilateral OA right leg versus control right leg: SMD, –1.64; 95% CI: –2.28, –0.99; –53.71%  
• Bilateral OA left leg versus control left leg: SMD, –1.37; 95% CI: –1.99, –0.75; –40.69%  
• Flexion  
• Unilateral OA versus control: SMD, –0.61; 95% CI: –1.18, –0.04; –22.13%  
• Bilateral OA right leg versus control right leg: SMD, –1.64; 95% CI: –2.28, –0.99; –49.60%  
• Bilateral OA left leg versus control left leg: SMD, –1.37; 95% CI: –1.99, –0.75; –45.86%  
• Extension  
• Unilateral OA versus control: SMD, –1.15; 95% CI: –1.75, –0.55; –43.65%  
• Bilateral OA right leg versus control right leg: SMD, –2.29; 95% CI: –3.02, –1.57; –65.59%  
• Bilateral OA left leg versus control left leg: SMD, –1.80; 95% CI: –2.46, –1.13; –54.58%  
• IR  
• Unilateral OA versus control: SMD, –0.91; 95% CI: –1.49, –0.32; –54.75%  
• Bilateral OA right leg versus control right leg: SMD, –1.14; 95% CI: –1.75, –0.54; –36.57%  
• Bilateral OA left leg versus control left leg: SMD, –1.73; 95% CI: –2.39, –1.08; –53.10%  
• ER  
• Unilateral OA versus control: SMD, –1.01; 95% CI: –1.60, –0.42; –47.38%  
• Bilateral OA right leg versus control right leg: SMD, –1.71; 95% CI: –2.37, –1.06; –51.17%  
• Bilateral OA left leg versus control left leg: SMD, –1.16; 95% CI: –1.76, –0.56; –45.90%  |

Table continues on page 633.
studies in meta-analysis had a mix of unilateral and bilateral participants, (3) imprecision (downgraded if upper or lower CI spanned an SMD of 0.5 in either direction), and (4) risk of bias (downgraded if modified Downs and Black score averaged less than 60%). Quality was defined as high, moderate, low, or very low.5

#### RESULTS

**Study Selection**

The search strategy returned 1737 articles (FIGURE 1). After screening 102 full texts for eligibility, 5 studies were included in the review.4,10,25,39,44 Three studies contained sufficient information to be pooled in a meta-analysis to compare peak isometric hip strength in people with knee OA to that in a control group of healthy individuals.4,25,44 Two studies were able to be pooled to compare isokinetic strength.4,25,44 No studies that assessed hip strength as a risk factor for knee OA development (secondary aim) were identified.

**Assessment of Risk of Bias**

Risk of bias was assessed across 15 items (TABLE 1).4 Quality scores ranged from 9 to 14, with an average of 12.2 (81%). All studies performed well in the risk-of-bias assessment, except for binding of assessors (item 15) in 4 out of the 5 studies,4,25,39,44 and it was not clear whether recruitment of controls and OA participants occurred at the same time point (item 22). One study did not report on the source of the population (item 11).44 Another study had a significant difference in confounders between the control and OA groups (item 12).25

**Study Characteristics**

Study characteristics are presented in TABLE 2. Four of the studies were case-control studies4,10,25,44 and 1 study used a nonequivalent, 2-group, preintervention-postintervention design.29 There were 237 knee OA participants across all studies, and these were matched to 140 control participants. Sample sizes varied between studies (n = 26 to 89 OA par-

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**TABLE 2**

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<th>Strength Outcome Measure</th>
<th>Results*</th>
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</table>
| Hinman et al5     | n = 89; 43 female; mixed cohort of unilateral and bilateral knee OA, with more severe OA limb used in bilateral participants; age, 64.6 ± 8.3 y; radiographic severity, KL grade >1 | n = 23; 16 female; age, 60.3 ± 6.5 y | Isometric peak torque: flexion, IR, ER, abduction, adduction, extension; flexion, IR, ER in sitting; hips and knees flexed to 90°; extension with hip flexed 20°; abduction and adduction in supine | Abduction  
  - OA versus control: SMD, –0.59; 95% CI: –1.05, –0.12  
  - OA grade 3 versus control: SMD, –0.04; 95% CI: –0.89, 0.81; –1.16%  
  - OA grade 2 versus control: SMD, –0.34; 95% CI: –1.02, 0.35; –11.63%  
  - OA grade 1 versus control: SMD, –0.08; 95% CI: –0.80, 0.65; –2.33% |

| Sled et al9       | n = 40; 23 female; age, 62.98 ± 9.73 y; radiographic severity, mean ± SD KL grade of 2.5 ± 0.9 | n = 40; 23 female; age, 64.3 ± 9.04 y | Isokinetic peak torque (Nm/kg): abduction (0°-30° ROM at 60°/s) | Adduction  
  - OA versus control: SMD, –0.47; 95% CI: –0.93, –0.01; –16.33%  
  - OA grade 1 versus control: SMD, –0.13; 95% CI: –0.72, 0.46; –16.67%  
  - OA grade 2 versus control: SMD, –0.34; 95% CI: –1.02, 0.35; –11.63%  
  - OA grade 3 versus control: SMD, –0.08; 95% CI: –0.80, 0.65; –2.33% |

| Yamada et al4b    | n = 49 knees of 32 participants (32 female); age, 62.3 ± 8.0 y; radiographic severity subgrouped by modified Ahlbäck criteria: grade 1 (n = 17 knees, 14 participants; age, 58.1 ± 8.7 y), grade 2 (n = 23 knees of 16 participants; age, 63.5 ± 6.7 y), grade 3 (n = 9 knees of 5 participants; age, 67.0 ± 6.7 y) | n = 13 (13 female); age, 60.5 ± 6.5 y | Isometric peak torque (kg): abduction, adduction | Abduction  
  - OA total versus control: SMD, –0.22; 95% CI: –0.83, 0.39; –6.98%  
  - OA grade 1 versus control: SMD, –0.08; 95% CI: –0.80, 0.65; –2.33%  
  - OA grade 2 versus control: SMD, –0.34; 95% CI: –1.02, 0.35; –11.63%  
  - OA grade 3 versus control: SMD, –0.04; 95% CI: –0.89, 0.81; –1.16%  |

**Abbreviations:**  CI, confidence interval; ER, external rotation; IR, internal rotation; KL, Kellgren-Lawrence; OA, osteoarthritis; ROM, range of motion; SMD, standardized mean difference.

*Values are between-group differences and percent difference [(OA - control)/control × 100]. Positive values indicate that strength in the OA group is greater than that in the control group.

†Data not used in meta-analysis.
participants). The majority of the OA participants were female (168 female, 69 male). Radiographic knee OA confirmation was performed using the Kellgren-Lawrence criteria in 4 studies and the modified Ahlbäck criteria in 1 study. All control participants were age and sex matched or the data within studies were appropriately adjusted for group differences.

**Isometric Strength**

Isometric muscle strength was measured by peak torque (Newton meters), body-weight-normalized peak torque (Newton meters per kilogram), or absolute force (kilograms).

**Abduction** Three studies assessed isometric hip abduction strength in 143 participants (150 limbs, 87 female) with knee OA compared to 50 control participants. When considered independently, people with knee OA were 7% to 24% weaker in hip abduction than control participants. In only 1 study was the difference statistically significant, such that people with knee OA (Kellgren-Lawrence grade greater than 1) were 24% weaker than controls (large difference, –0.91; 95% CI: –1.38, –0.43). When the 3 studies were combined in a meta-analysis, there was moderate-quality evidence (TABLE 3) of moderately significant lower hip abduction strength in people with knee OA (SMD, –0.60; 95% CI: –1.04, –0.17; I² = 54%) (FIGURE 2). The quality of evidence was downgraded because of indirectness, as the measure of hip strength dynamometry differed across studies.

**Adduction** Two studies assessed isometric hip adduction strength in 121 participants (138 knees, 75 female) with knee OA and 36 control knees. Only 1 study identified a significant difference between groups, where people with knee OA were 24% weaker than controls (moderate difference, –0.79; 95% CI: –1.26, –0.32). Conflicting results were found by Yamada et al, who reported that people with knee OA had 14% stronger hip adduction strength than controls, although this was not statistically significant (small difference, 0.30; 95% CI: –0.31, 0.92). When combined in a meta-analysis (FIGURE 2), there was very low-quality evidence (TABLE 3) of no significant difference between groups (SMD, –0.26; 95% CI: –1.33, 0.81; I² = 87%; 24% weaker to 14% stronger). The quality of evidence was downgraded due to inconsistency (high statistical heterogeneity), indirectness (different dynamometry technique), and imprecision (wide CIs).

**Other** One study investigated isometric hip strength in the sagittal (flexion/extension) and transverse (internal/external rotation) planes of 89 people with knee OA (Kellgren-Lawrence grade greater than 1) compared to 23 control participants. There is limited evidence that people with knee OA have significantly weaker hip internal and external rotation strength compared to control participants (small to moderate difference, P<.05) (TABLE 4). In the sagittal plane, there was limited evidence of a large and significant reduction in hip flexion strength (P<.05) (TABLE 2), while there was no significant difference in hip extension strength (P>.05) (TABLE 2).

**Isokinetic Strength**

Isokinetic strength was assessed in 2 studies and expressed as peak torque (Newton meters) in 1 study and as body-weight-normalized peak torque (Newton meters per kilogram) in another study. Combined, the studies assessed peak isokinetic torque in 90 people with knee OA (67 female) and 90 healthy control participants. One study included 25 participants with unilateral knee OA and 25 participants with bilateral knee OA. The authors matched each group (unilateral and bilateral) to a separate cohort of control participants, so that both groups were able to be combined in a meta-analysis without duplicating control-participant data. For the bilateral knee OA group, the more conservative SMD from the right or left limb was used in pooled analysis.
**DISCUSSION**

The isokinetic hip abduction data of both studies were able to be pooled in a meta-analysis. The results suggest moderate-quality evidence that isokinetic hip abduction strength is significantly weaker (by 14% to 32%) in people with knee OA compared to controls (moderate difference, –0.55; 95% CI: –0.85, –0.26; I² = 0%). The quality of evidence was downgraded due to indirectness (mix of unilateral and bilateral participants).

Data for the remaining isokinetic hip directions were able to be pooled for the unilateral and bilateral participants in the study by Costa et al. The pooled data indicate that people with knee OA are significantly weaker in isokinetic hip abduction (41% to 50% weaker), flexion (22% to 46% weaker), extension (44% to 55% weaker), external rotation (46% to 47% weaker), and internal rotation (37% to 38% weaker) than controls (large difference: SMD, greater than –0.98) (Figure 3). The quality of evidence ranged from very low to moderate (Table 3).

The current systematic review provides moderate evidence that hip abductor weakness is also associated with a distal joint pathology: knee OA. Clinicians and researchers can be moderately confident that the pooled effect estimates for hip abduction strength differences represent the true population effect.

The contribution of hip abductor weakness to knee OA development is unknown. There were no prospective studies that investigated hip strength as a risk factor for knee OA diagnosis. Theoretically, as indicated through biomechanical modeling, weak hip abductors can result in pelvic malalignment, increasing medial knee joint load and leading to the development and progression of knee OA. Recently, a significant relationship between hip abductor strength and external knee adduction moment (a measure of knee load) was identified in people with knee OA. However, hip abductor strength only explained 10% of the variability in knee load, suggesting that other factors may be more important in knee OA development and that hip abductor weakness may be a result of knee OA, not a cause. Nevertheless, this remains speculation, without evidence from prospective trials that include a measure of hip muscle strength.
FIGURE 3. Forest plot comparing isokinetic hip muscle strength in people with knee osteoarthritis to that in healthy control participants.

Abbreviations: IV, independent variable; SMD, standardized mean difference.

*Test for subgroup differences: $\chi^2 = 11.11, df = 5 (P = .05), I^2 = 55%$.

1 Heterogeneity: $F^2 = 0.00, \chi^2 = 1.10, df = 2 (P = .58), I^2 = 0%. Test for overall effect: z = 3.64 (P = .0003).$

2 Heterogeneity: $F^2 = 0.00, \chi^2 = 0.47, df = 1 (P = .49), I^2 = 0%. Test for overall effect: z = 5.53 (P < .00001).$

3 Heterogeneity: $F^2 = 0.20, \chi^2 = 3.13, df = 1 (P = .08), I^2 = 68%. Test for overall effect: z = 2.37 (P = .01).$

4 Heterogeneity: $F^2 = 0.11, \chi^2 = 2.00, df = 1 (P = .16), I^2 = 50%. Test for overall effect: z = 4.31 (P < .00001).$

5 Heterogeneity: $F^2 = 0.00, \chi^2 = 0.43, df = 1 (P = .72), I^2 = 0%. Test for overall effect: z = 5.03 (P < .00001).$

6 Heterogeneity: $F^2 = 0.00, \chi^2 = 0.31, df = 1 (P = .58), I^2 = 0%. Test for overall effect: z = 4.78 (P < .00001).

Hip adductor strength deficits in people with knee OA are less conclusive. There is very low-quality evidence that people with knee OA have isometric hip adduction strength comparable to that of healthy controls (24% weaker to 14% stronger). However, given the wide CIs in the pooled results and the conflicting findings from the 2 studies involved, it is highly likely that further work will change the estimated SMD and statistical significance. Additionally, the moderate-quality evidence of weaker hip adductor isokinetic strength is at odds with the isometric strength findings. Recent imaging studies indicate that the adductors have a more important contribution to functional tasks like walking than previously.
thought. It is also possible that this role is heightened in people with knee OA, particularly those with knee varus malalignment. Yamada et al suggest that the adductor muscles may act to reduce the knee-related varus angulation and consequently unload the arthritic compartment in the knee. The inconclusive results of the current review clearly identify an important gap in our understanding of hip adductor–related strength deficits in people with knee OA and provide a specific avenue for further research. Bridging this gap may provide evidence for innovative interventions that target hip adductors in people with knee OA, a strategy that to date remains untested.

Further research is also required to investigate hip strength deficits in the sagittal (flexion/extension) and transverse (internal/external rotation) planes. Only 1 study investigated these actions isometrically, and 1 isokinetically, with limited to moderate-quality evidence of weaker hip strength in people with knee OA. While these results support interventions for strengthening the hip muscles in the sagittal and transverse planes, further work is likely to change the effect estimate and is therefore required to improve our confidence in the findings.

The results of the current review should be viewed in light of its strengths and limitations. It is the first review to compile evidence of hip strength deficits in people with knee OA and has adhered to PRISMA guidelines. This review has also consolidated the results of multiple independent studies by pooling SMDs in a meta-analysis for a range of hip actions. Each meta-analysis has also been rated in terms of the quality of evidence, using a modified GRADE approach and taking into account statistical and clinical heterogeneity, the width of the CI, and the risk of bias across studies. In doing so, the findings support the need for clinicians and researchers to consider assessing and treating hip strength deficits in people with knee OA.

Despite these strengths, there are also limitations to consider. Some of the meta-analyses were statistically heterogeneous, with I² values of up to 87%. There were also examples of clinical heterogeneity, with the knee OA participants ranging in diagnosis and number of limbs involved (unilateral, bilateral). Further, the method of measurement differed across studies. For example, Yamada et al placed the dynamometer at the ankle, while Hinman et al placed it at the distal thigh. The use of different handheld dynamometry placement locations can potentially exacerbate inherent issues in interrater reliability of this technique. Additionally, the speed of isokinetic strength testing differed between studies (TABLE 2). These inconsistencies could impact the strength of findings in the review but were considered in the GRADE criteria, with the quality of the findings downgraded accordingly. Finally, we were unable to screen full texts of potentially eligible non-English articles, so this review may be subject to language bias. The abstract of only 1 non-English article was deemed potentially eligible, thus limiting this source of bias.

The results of this review have important clinical implications. It is well accepted that any exercise performed and monitored regularly will improve physical function and pain in people with knee OA. Unknown are the optimal dose and type of exercise that would maximize outcomes over sustained periods. There are few studies that have evaluated targeted hip strengthening in knee OA as a management strategy; consequently, evidence to guide clinical decisions with regard to this is incomplete. The current review identified hip strength deficits that may potentially be targeted to optimize the outcomes of rehabilitation. For example, when considering isometric muscle strength, the current study identified hip abductor strength deficits of between 7% and 24% in people with knee OA. This is deemed to be a moderate difference and up to 2 times greater than the 10% deficit considered to be clinically meaningful. Hip abductor strengthening may therefore be a further option for targeted intervention, or, at the very least, clinicians should consider incorporating hip abductor strength assessment into routine clinical practice. While this review identified hip strength deficiencies in people with symptomatic knee OA, it is not possible to provide a single value to identify those in the clinic who are weak and those who are not. It is important, then, to consider measuring the strength of participants or patients at baseline and monitoring changes over time.

### CONCLUSION

**P**eople with symptomatic knee OA present with hip strength deficits. There is moderate-quality evidence that people with knee OA have significantly weaker isometric and isokinetic hip abductor strength compared to healthy controls. Further work is needed to support the current findings on hip abductor strength, as well as sagittal and transverse plane hip strength. Prospective studies are required to determine whether hip strength is a risk factor for the development of knee OA; however, in the meantime, it is recommended that baseline hip strength assessment be incorporated into common clinical practice in those diagnosed with knee OA.

### KEY POINTS

**FINDINGS:** There are hip strength deficits in people with symptomatic knee OA compared to control participants. This is particularly evident with hip abduction (up to 24% weaker in isometric strength), and further work is required to confirm weakness in the remaining hip actions.

**IMPLICATIONS:** Hip strength assessment should be considered in clinical practice and may assist with directing targeted management strategies for knee OA.

**CAUTION:** This review has not differentiated between stages of pathology or sexes. The association between hip strength deficits and the development of knee OA is currently unknown.

REFERENCES


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### APPENDIX

#### Search Strategy for MEDLINE and CINAHL
1. Musc* atrophy  
2. Musc* endurance  
3. MH 'Muscle Weakness'  
4. MH 'Muscular Atrophy'  
5. Musc* weak*  
6. Musc* reeduca*  
7. Musc* cross section* area  
8. Musc* CSA  
9. Musc* size  
10. MH 'Muscle Strength'  
11. Musc* strength  
12. Isokinetic dynamomet*  
13. MH Electromyography  
14. EMG  
15. Electromyograph*  
16. Musc* activ*  
17. Musc* volume  
18. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17  
19. MH 'Osteoarthritis Knee'  
20. Knee arthrit*  
21. Knee osteoarthrit*  
22. Knee OA  
23. 19 OR 20 OR 21 OR 22  
24. 18 AND 23

#### Search Strategy for the Cochrane Library
1. Musc* atrophy  
2. Musc* endurance  
3. MH 'Muscle Weakness'  
4. MH 'Muscular Atrophy'  
5. Musc* weak*  
6. Musc* reeduca*  
7. Musc* cross section* area  
8. Musc* CSA  
9. Musc* size  
10. MH 'Muscle Strength'  
11. Musc* strength  
12. Isokinetic dynamomet*  
13. MH Electromyography  
14. EMG  
15. Electromyograph*  
16. Musc* activ*  
17. Musc* volume  
18. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17  
19. MH 'Osteoarthritis Knee'  
20. Knee arthrit*  
21. Knee osteoarthrit*  
22. Knee OA  
23. 19 OR 20 OR 21 OR 22  
24. 18 AND 23

#### Search Strategy for PsycINFO
1. Musc* atrophy  
2. Musc* endurance  
3. MH 'Muscular Atrophy'  
4. Musc* weak*  
5. Musc* reeduca*  
6. Musc* cross section* area  
7. Musc* CSA  
8. Musc* size  
9. Muscle Strength  
10. Musc* strength  
11. Isokinetic dynamomet*  
12. MH Electromyography  
13. EMG  
14. Electromyograph*  
15. Musc* activ*  
16. Musc* volume  
17. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17  
18. Knee arthrit*  
19. Knee osteoarthrit*  
20. Knee OA  
21. 18 OR 19 OR 20  
22. 17 AND 23

#### Search Strategy for Embase
1. Musc* AND atrophy  
2. Musc* AND endurance  
3. Emtree: 'Muscle Weakness'  
4. Emtree: 'Muscular Atrophy'  
5. Musc* weak*  
6. Musc* reeduca*  
7. Musc* cross section* area  
8. Musc* CSA  
9. Musc* size  
10. Emtree: 'Muscle Strength'  
11. Musc* strength  
12. Emtree: 'Isokinetic dynamomet'  
13. Emtree: 'Electromyography'  
14. EMG  
15. Emtree: 'Electromyograph'  
16. Musc* activ*  
17. Musc* volume  
18. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17  
19. Emtree: 'Knee Osteoarthritis'  
20. Knee arthrit*  
21. Knee osteoarthrit*  
22. Knee OA  
23. 19 OR 20 OR 21 OR 22  
24. 18 AND 23